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(71) Applicant: **SGS-THOMSON MICROELECTRONICS s.r.l.**
Via C. Olivetti, 2
I-20041 Agrate Brianza Milano(IT)

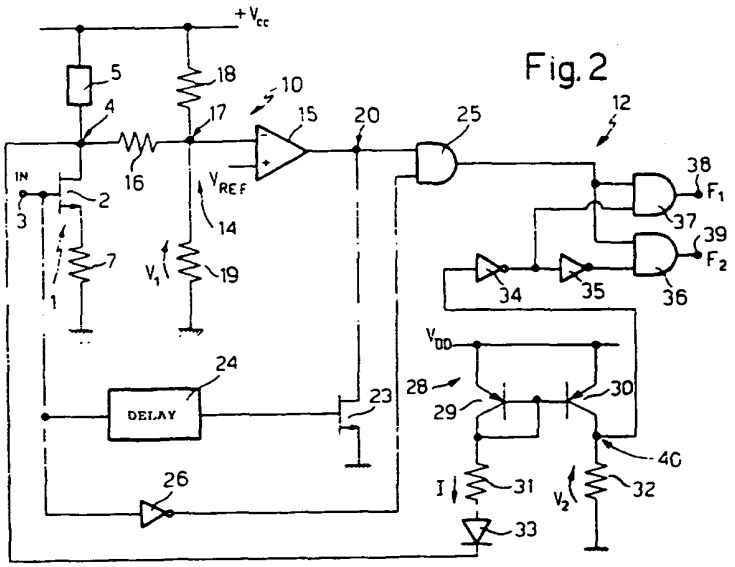
(72) Inventor: **Brambilla, Massimiliano**
Viale Casiraghi, 53
I-20099 Sesto San Giovanni(IT)
Inventor: **Maggioni, Giampietro**
Via Ghisolfa, 113
I-20010 Cornaredo(IT)

(74) Representative: **Cerbaro, Elena et al**
c/o Studio Torta, Via Viotti 9
I-10121 Torino(IT)

(54) Drive circuit fault detection device.

(57) A drive circuit fault detection device comprising an discriminating circuit (10) generating a digital signal, the level of which indicates a fault; and an identifying circuit (12) generating a binary-coded signal (F1, F2) indicating the type of fault, i.e. ground shorting of the drive circuit (1) or an open load (5). The discriminating circuit (10) comprises a resistive network (14) connected to the output (4) of the drive circuit (1), for generating a voltage (V_1) indicating correct connection of the load (5) or a fault on the drive circuit (1); and a comparator (15) for comparing the aforementioned voltage with a reference value (V_{REF}) and supplying the digital signal. The identifying circuit (12) comprises a current mirror circuit (28) generating an output voltage (V_2) having two different logic levels in the event of short circuiting or an open load (5), the binary-coded output signal (F1, F2) being generated by a combination circuit (34-37).

Fig. 2



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The present invention relates to a drive circuit fault detection device, in particular, for output short circuiting or disconnected load detection.

In the following description, reference will be made to a so-called low-side-driver circuit, i.e. wherein the drive circuit is grounded and the load connected to a positive supply, thus requiring detection of ground shorting of the circuit output. The present invention, however, is equally applicable to so-called high-side-driver circuits.

Fig.1 shows the overall structure of a low-side-driver circuit, wherein drive circuit 1 is shown schematically by its control element, consisting of a power transistor 2 having a first (control) terminal 3 receiving a control signal (IN); a second terminal 4 connected to positive supply line V_{CC} via load 5; and a third terminal 6 grounded via resistor 7. Terminal 4 of transistor 2 also defines the drive circuit output.

In the above known circuit, ground shorting of output 4, as shown schematically by dotted line 8, is detected by monitoring the current in the control element, normally by means of a sensing resistor frequently implemented by resistor 7 itself, shorting being indicated by failure of said current to reach a given value within a given length of time.

A major drawback of the above known solution is that it entails defining beforehand a short-circuit resistance which, to ensure correct detection, must be decidedly less than the equivalent resistance of control element 2.

It is an object of the present invention to provide a fault (specifically, ground shorting) detection device, which, by virtue of not requiring a predefined short-circuit resistance, does not entail detecting or monitoring the current in the control element.

According to the present invention, there is provided a drive circuit fault detection device as claimed in Claim 1.

A preferred, non-limiting embodiment of the present invention will be described with reference to the accompanying drawings, in which:

Fig.1 shows a simplified electric diagram of a drive circuit to which the present invention is applied;

Fig.2 shows a simplified electric diagram of one embodiment of the device according to the present invention.

The drive circuit components common to both Fig.s 1 and 2 are shown using the same numbering system.

As shown in Fig.2, the fault detection device according to the present invention comprises a fault discriminating circuit 10 for generating a predetermined (e.g. high) logic output signal in the presence of a fault (shorting of output 4 of drive circuit 1, or disconnected load 5); and a fault identifying circuit 12 for identifying the type of fault involved.

More specifically, discriminating circuit 10 comprises voltage generating means 14 connected to output 4 of drive circuit 1, for generating different voltage levels depending on the presence or absence of a fault between output 4 and load 5; and a comparator 15 for comparing said voltage level with a reference voltage, and generating a digital fault output signal. Voltage generating means 14 in turn consist of a resistive network 14 comprising a first resistor 16 having a first terminal connected to output 4 of circuit 1, and a second terminal connected to mid point 17 of a voltage divider. This in turn consists of a second resistor 18 connected between mid point 17 and supply line V_{CC} (first reference potential line); and a third resistor 19 connected between mid point 17 and ground (second reference potential line). Comparator 15 presents its inverting input (-) connected to mid point 17, and its non-inverting input (+) connected to a reference voltage obtainable in known manner from the supply voltage via a further voltage divider. Output 20 of comparator 15 also defines the output of discriminating circuit 10.

Output 20 is connected to the drain terminal of a transistor 23, which acts as a switch for selectively grounding output 20, for which purpose, the source terminal of transistor 23 is grounded, and the gate terminal connected to the output of a delay circuit 24, the input of which is connected to control terminal 3 of transistor 2.

Output 20 is connected to one input of a two-input AND circuit 25, the other input of which is connected to control terminal 3 via an inverter 26, so that the signal at output 20 (possibly after a given delay set by means of circuit 24) is only supplied to identifying circuit 12 in the absence of control signal IN (i.e. when the drive circuit is disabled).

Identifying circuit 12 comprises a current mirror circuit 28 consisting of a first and second PNP transistor 29, 30 having emitter terminals connected to a second supply line V_{DD} generally differing from the first V_{CC}; mutually connected base terminals; and collector terminals connected to respective resistors 31 and 32. Transistor 29 is also diode-connected, i.e. presents short-circuited base and collector terminals. Resistor 31 is located between the collector of transistor 29 and the anode of a diode 33, the cathode of which is connected to output 4 of drive circuit 1; while resistor 32 is connected between the collector of

transistor 30 and ground. The collector of transistor 30, defining output 40 of mirror circuit 28, is also connected to one input of a two-input AND circuit 36 via the cascade connection of two inverters 34, 35; while the mid point of inverters 34, 35 is connected to one input of a further two-input AND circuit 37. The second input of both AND circuits 36, 37 is connected to the output of circuit 25. Respective outputs 38, 39 of circuits 37, 36 constitute the outputs of the detection device respectively supplying signals F1, F2, which together define a binary signal.

The Fig.2 device operates as follows. If R1, R2 and R3 are the respective resistances of components 18, 19 and 16, and assuming, for the sake of simplicity, a negligible resistance of load 5 (as is invariably the case with inductive loads such as internal combustion engine injectors or solenoids having a resistance of a few Ohms), the voltage V_1 at point 17 equals:

$$V_{1a} = V_{CC} * \frac{R2}{R2 + R1//R3}$$

if the load is connected;

$$V_{1b} = V_{CC} * \frac{R2}{R1 + R2}$$

if the load is disconnected (open); and

$$V_{1c} = V_{CC} * \frac{R2//R3}{R1 + R2//R3}$$

in the event of a short circuit between output 4 and ground.

By appropriately sizing the resistors, therefore, it is possible to distinguish between connected load and fault situations. More specifically, as voltage V_1 is maximum when the load is connected, by selecting a reference voltage V_{REF} of comparator 15 slightly lower than V_{1a}, but higher than V_{1b} and V_{1c}, output 20 of the comparator will be low when the load is connected, and high in the event of a fault.

By way of example, suitable resistance values for components 16, 18 and 19 may be:

R1 = 30 KΩ
R2 = 60 KΩ
R3 = 1 KΩ

With these values and a supply voltage V_{CC} = 16 V:

V_{1a} = 15.75 V
V_{1b} = 10.67 V
V_{1c} = 508 mV

so that any faults may safely be determined with a reference voltage V_{REF} between 15 and 10 V.

To prevent false alarm signals during operation of drive circuit 1 (the low resistance of which would prevent normal operation being distinguished from a fault situation), the output signal from comparator 15 can only be supplied to identifying circuit 12 when circuit 1 is disabled (low-level control signal IN) and, consequently, circuit 25 enabled. Also, to allow output 4 of circuit 1 to settle, circuit 24 provides for delaying the reading of comparator 15 following switching of control signal IN. In fact, when control signal IN switches to low, delay circuit 24 supplies an output pulse for turning on transistor 23 and so grounding output 20 regardless of the value of voltage V_1, so that the output of circuit 25 is low. At the end of the pulse generated by delay circuit 24, transistor 23 goes off, thus enabling the output of comparator 15 to switch to

the logic state corresponding to the level of voltage V_1, so that the output of circuit 25 presents a high signal in the event of a fault, or a low signal if the load is connected.

The type of fault is distinguished by means of circuit 12. In the event of a short circuit at output 4, the cathode of diode 33 is grounded, and the reference branch consisting of components 29, 31 and 33 of mirror circuit 28 presents a current I of:

$$I = (V_{DD} - 2V_{BE})/R4$$

where V_{BE} is the base-emitter voltage drop of transistor 29 and diode 33, and R4 the resistance of resistor 31. The above current is mirrored in the branch consisting of components 30 and 32, and, in resistor 32, produces a voltage drop V_2 of:

$$V_2 = R5 \cdot (V_{DD} - 2V_{BE})/R4$$

where R5 is the resistance of resistor 32. Thus, by appropriately sizing resistors R4 and R5 (e.g. both of the same value), it is possible to obtain a high logic level voltage V_2 at output 40.

Conversely, in the event load 5 is disconnected (open), resistors 16 and 18 of the discriminating circuit produce a high voltage at output 4 (pull-up situation) such as to disable mirror circuit 28 and produce a zero voltage in resistor 32 (low logic level V_2 voltage signal at output 40). Finally, diode 33 also provides for disconnecting identifying circuit 12 if load 5 is connected and during operation of drive circuit 1, to prevent it from interfering with normal operation of the drive circuit. The combination circuit consisting of components 34-37 thus provides for distinguishing between the various situations involved.

More specifically, if F1 and F2 are the signals at outputs 38 and 39:

F1	F2	Situation
0	0	connected load
0	1	open load
1	0	ground short circuit
1	1	not permitted

The above signals may thus be supplied to downstream circuits for generating specific signals or commands.

The advantages of the Fig.2 device will be clear from the foregoing description. In particular, it does not entail a predefined short circuit resistance, which has substantially no effect anyway on the parallel connection of resistors 16 and 19; it provides for a wider range of diagnostic functions by also detecting open-load situations; it is straightforward in design, can be implemented easily and even fully integrated, thus providing for low-cost manufacture and a high degree of reliability; and, last but not least, it does not interfere with normal operation of, or require alterations to, drive circuit 1, by virtue of being connected directly to output 4.

To those skilled in the art it will be clear that changes may be made to the device as described and illustrated herein without, however, departing from the scope of the present invention. In particular, the discriminating circuit may consist of nonresistive elements, providing they supply a voltage indicating a fault (short circuit or open load) on the drive circuit-load connection; and the identifying circuit may comprise, for example, a pair of comparators with different references connected to the resistive network.

Claims

1. A fault detection device for a drive circuit (1) having an output (4) connected to a load (5), comprising a fault discriminating circuit (10), characterized in that said fault discriminating circuit (10) has an input coupled to the output (4) of the drive circuit (1) and an output (20) providing a digital signal indicative of a condition of a connection between the drive circuit and the load, the fault discriminating circuit (10) comprising a detector for determining when a fault exists in the connection between the drive circuit and the load.

2. A device as claimed in Claim 1, characterized by a fault identification circuit (12), coupled to the output (20) of the fault discriminating circuit (10) and including circuitry responsive to the digital signal provided by the fault discriminating circuit for providing a signal (F1, F2) indicative of a type of fault

detected by the fault discriminating circuit.

3. A device as claimed in Claim 1 or 2 for a drive circuit (1) comprising a control element (2) having a first control terminal (3) receiving a control signal (IN); a second terminal (4) connected to a first reference potential line (V_{CC}) via said load (5); and a third terminal (6) connected to a second reference potential line; characterized in that said fault discriminating circuit (10) comprises voltage generating means (14) connected to said second terminal (4) of said control element (2), for generating a voltage (V_1) indicating a fault on the connection between said control element and said load (5); and comparing means (15) for comparing said voltage (V_1) with a reference value (V_{REF}) and generating a corresponding fault signal.

4. A device as claimed in Claim 3, characterized by the fact that said generating means comprise a resistive network (14).

5. A device as claimed in Claim 4, characterized by the fact that said resistive network (14) comprises a first (18) and second (19) resistor series-connected between said first (V_{CC}) and said second reference potential line and defining a common connection point (17); and a third resistor (16) connected between said second terminal (4) of said control element (2) and said common connection point (17).

6. A device as claimed in any one of Claims 2 to 5, characterized by the fact that said comparing means (15) present an output (20) connected to a controlled switch (23) having a control terminal connected to said first control terminal (3) of said control element (2) via a delay circuit (24).

7. A device as claimed in one of Claims 3 to 6, characterized by a logic circuit (25) input-connected to said comparing means (15) and said control terminal (3), so as to block said fault signal in the presence of said control signal (IN).

8. A device as claimed in Claim 7, characterized by the fact that said logic circuit is an AND circuit (25) connected to said control terminal (3) via an inverter (26).

9. A device as claimed in any one of Claims 3 to 8, characterized by a fault identifying circuit (12) connected to said output (20) of said comparing means (15), for generating a binary-coded output signal (F1, F2) indicating a first state when said control element (2) and said load (5) are connected; a second state when a short circuit exists between said second terminal (4) and said second reference potential line; and a third state when said load (5) is disconnected.

10. A device as claimed in Claim 9, characterized by the fact that said fault identifying circuit (12) comprises a current mirror circuit (28) having an input terminal connected to said second terminal (4) of said control element (2), and an output terminal (40) presenting a different voltage value (V_2) in said second short-circuit state and said third open-load state; said output terminal (40) being connected to the input of a combination circuit (34-37) also connected to the output of said comparing means (15), for generating said binary signal.

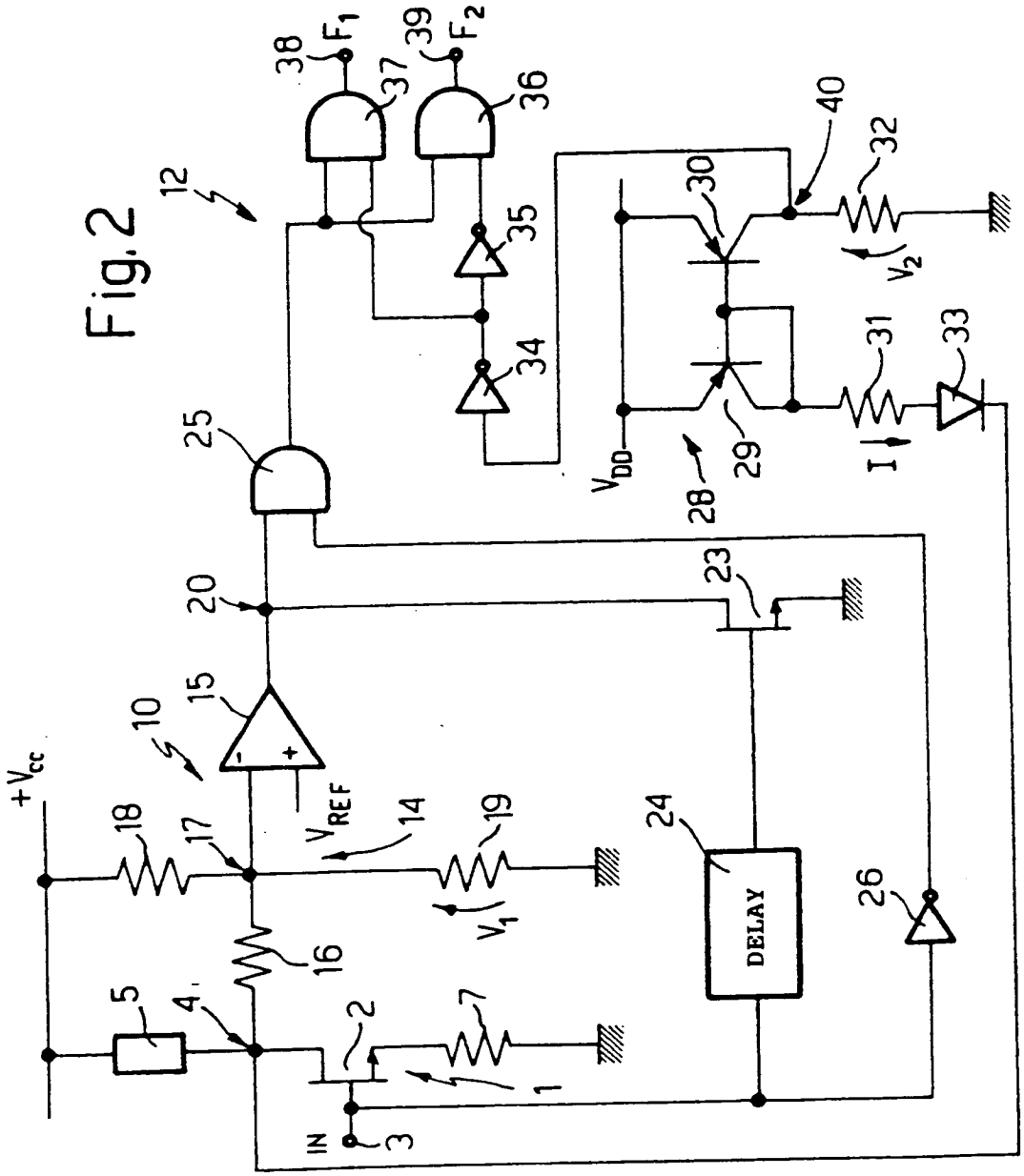
11. A device as claimed in Claim 10, characterized by the fact that said mirror circuit (28) comprises a first and second branch; by the fact that said first branch comprises a first diode-connected bipolar transistor (29) having an emitter terminal connected to a third reference potential line (V_{DD}); and a first resistor (31) connected between the collector terminal of said first bipolar transistor (29) and the anode terminal of a diode (33), the cathode terminal of which is connected to said second terminal (4) of said control element (2) and defines said input terminal of said mirror circuit; and by the fact that said second branch comprises a second bipolar transistor (30) having an emitter terminal connected to said third reference potential line (V_{DD}), a base terminal connected to the base terminal of said first bipolar transistor (29), and a collector terminal connected to said second reference potential line via a second resistor (32); said collector terminal of said second bipolar transistor (30) defining said output terminal (40) of said current mirror circuit.

12. A device as claimed in Claim 10 or 11, characterized by the fact that said combination circuit comprises a first logic circuit (36) input-connected to said comparing means (15) and said output terminal (40) of said current mirror circuit (28); and a second logic circuit (37) input-connected to said

comparing means (15) and said output terminal (40) of said current mirror circuit (28) via an inverting element (34).

13. A device as claimed in any one of Claims 3 to 12, characterized by the fact that said first reference potential line defines a supply line (V_{CC}), and said second referential potential line defines the ground.

Fig.2


38
F1
39
F2
37
36
12
40
32
30
35
34
31
33
25
VDD
28
29
I
V2
20
23
10
15
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19
24
DELAY
26
V1
16
5
4
2
7
1
IN
3

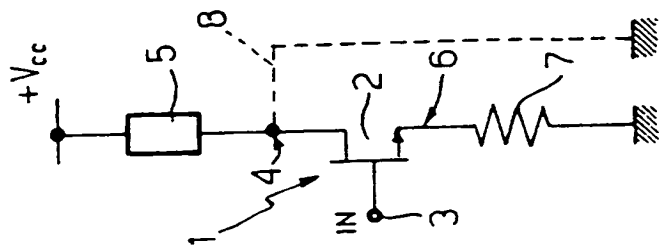
+Vcc
5
8
2
6
7
4
1
IN
3

Fig.1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 92 11 2118

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 418 665 (SIEMENS) * page 3, line 54 - page 9, line 10; figures 2-5 *	1,2	H03K17/08
A		3,4,7-9, 13	
X	US-A-4 750 079 (FAY ET AL) * column 1, line 12 - column 4, line 6; figures *	1-3,9,13	
A		7,8	
A	EP-A-0 128 574 (MOTOROLA) * page 6, line 22 - page 10, line 14; figures 1-3A *	1-3,9,13	
A	US-A-4 736 267 (KARLMANN ET AL) * column 3, line 51 - column 9, line 51; figures *	1,3,7,9, 13	
A	DE-A-4 035 571 (ALPS ELECTRIC CO. LTD.) * column 3, line 17 - column 6, line 6; figures 1-3 *	1-3,13	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H03K G01R
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 316 (P-510)28 October 1986 & JP-A-61 127 010 (MITSUBISHI ELECTRIC CORP.) 14 June 1986 * abstract *	1,2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	28 JANUARY 1993	P.TAYLOR

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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(71) Applicant: **SGS-THOMSON MICROELECTRONICS s.r.l.**
Via C. Olivetti, 2
I-20041 Agrate Brianza Milano(IT)

(72) Inventor: **Brambilla, Massimiliano**
Viale Casiraghi, 53
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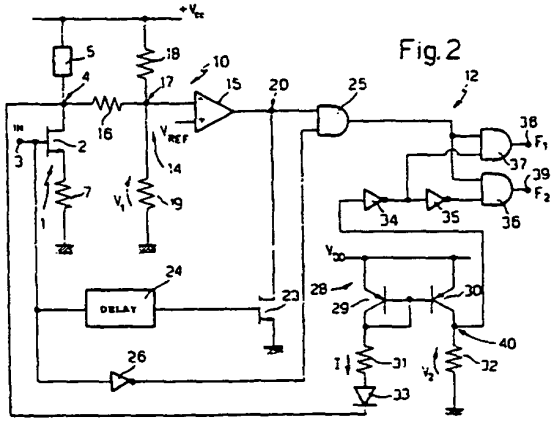

Fig. 2

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